ACTIVE COMPOUND PLASMA LIGHTNING (CPLR) REJECTION SYSTEM

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INTRODUCTION

The Brightex CPLR solution removes the risk and protects people, property and equipment from devastation and disruption triggered by lightning strikes.

Airports have lightning protection in place using present-day "lightning rod" technology. Yet airports continue to experience lightning damage and must shut down airside operations during a lightning event. Brightex offers an alternative protection that prevents lightning from striking the airport and allows operations to continue uninterrupted during a lightning event. Brightex has undertaken a mission to assist airports in managing risk that in turn minimizes physical and economic losses due to aircraft movement delays and ground labor delays. Our goal is to minimize operational interruptions, financial losses, and human injury or fatality wherever lightning is prevalent.

This new and innovative field-tested and verified technology provides a proactive alternative for the current standard of passive lightning protection for property, equipment, and people. The most recent installation is at the Bali International Airport, where every year they experienced operational interruptions due to lightning strikes even with lightning rod protection. Since the new technology has been installed, the airport has experienced *NO interruptions* due to lightning strikes. The unit has been in place through two lightning (monsoon) seasons.

The purpose of this paper is to:

I. Define lightning and the associated dangers.
II. Discuss current passive lightning protection methods.
III. Present the **First** and only **ACTIVE** lightning protection system.
IV. Present Brightex's history.
V. Summary: Why the Brightex CPLR is Superior.

I. LIGHTNING AND ASSOCIATED DANGERS

I.a. Definition of Lightning

The Flight Safety Foundation has written a succinct article on the definition of lightning:

"Lightning is a discharge of electricity that occurs in the atmosphere and can be thought of as a high-current—about 20,000 amperes—electric spark associated with thunderstorms.

Lightning is produced when super-cooled liquid and ice particles above the freezing level collide and build up large and separate regions of positive and negative electric charges in the clouds. After these charges become large enough, a giant 'spark,' or discharge, occurs between them, lasting less than a tenth of a second. The spark—lightning—can occur between clouds, between sections of a single cloud, between the cloud and air, or between the cloud and the ground (known as cloud to ground lightning)—or some object on the ground.

The most common type of lightning discharge is cloud-to-ground, or 'negative' lightning, which accounts for 90 percent of all lightning strikes. The discharge usually begins when a significant difference develops between the negative charge in the cloud and the positive charge on the ground—or in another cloud. At this point, the negative charge begins moving toward the ground, forming an invisible conductive path, known as a leader stroke. This leader stroke descends through the air in discrete zigzag steps, or jumps, each approximately 150 ft. (46 m) long. Concurrently, a positively charged streamer is sent out from the positively charged ground or other cloud. When the leader and the streamer meet, an electrical discharge—lightning—takes place along the streamer, up and into the cloud. It is this return stroke that is the most luminous part of the lightning discharge, usually the only part of the lightning process that is actually seen.

Another type of lightning—known as 'positive lightning' because there is a net transfer of positive charge from the cloud to the ground—originates in the upper parts of a thunderstorm, where a high positive charge resides. This type of lightning develops almost the same way as negative lightning, except that the descending stepped leader carries a positive charge and the subsequent ground streamer has a negative charge. Positive lightning accounts for less than 5 percent of all lightning but is much more powerful, lasts longer and can discharge at greater distances than the more common negative lighting.

Lightning is a global phenomenon. Flashes have been seen in volcanic eruptions, intense forest fires, heavy snowstorms and large hurricanes; however, it is most often associated with thunderstorms.

While global in occurrence, lightning is not uniformly distributed geographically. About 70 percent of all lightning flashes occur between 30 degrees N and 30 degrees S latitudes—not surprisingly, in the tropics, where most thunderstorms occur. In addition, lightning over land, or over water that is close to land, is 10 times more frequent than lightning over oceans." [1]

I.b. Dangers of Lightning

Dr. Martin A. Uman is considered an expert in the study of lightning knowledge and protection. To quote Dr. Uman from his book *The Art and Science of Lightning Protection*: "A lightning strike to an unprotected object or system can be disastrous—in the United States lightning is responsible for over 30 percent of all electric power failures; causes property damage resulting in insurance claims of billions of dollars; and accounts for an average of 85 fatalities a year, and probably 10 times as many injuries." [2]

As Dr. Uman clearly states in his introduction, this book is a must read for any person (including insurance companies) wanting to understand lightning and the business of lightning protection for property, equipment and people. He discusses all aspects of passive lightning protection at a moderately technical level with many illustrative drawings and photographs. Included in the discussion, as they pertain to current passive lightning protections, are the salient aspects of the 2004 U.S. lightning protection standard NFPA 780 and the 2006 IEC (International Electrotechnical Commission) lightning protection standards. He highlights the role of lightning detection and warning for effective protection with current techniques. He also considers options for deflecting or eliminating lightning.

Lightning is a strong force of nature that can cause damage anywhere there are lightning storms. It is an atmospheric discharge of electricity and an *equal opportunity force* damaging property, equipment, and people. There are three types of lightning: cloud to ground (most prevalent), cloud to cloud, and intracloud.

Most people survive a lightning strike, but the survivors typically have disturbing stories to tell and often suffer debilitating injuries. Facilities can be completely devastated as a result of a lightning strike, and even if the building should survive, equipment in or near the building is usually damaged and/or destroyed. Thanks to education, the number of lost lives has decreased but has not been eliminated. A lightning map of the world (***http://news.nationalgeographic.com/news/2003/05/photogalleries/lightning/photo3.html***) shows where lightning is MOST active. While global in occurrence, lightning is not uniformly distributed geographically. In the U.S., the high-lightning area is the southeast corner of the country, from the Coastal Carolinas south to Florida and across the Gulf Coast to Texas. There are other pockets scattered from coast to coast.

II. CURRENT PASSIVE LIGHTNING PROTECTION

Deflection of lightning has been the standard since Benjamin Franklin invented the lightening rod in 1753. Building codes and standards are based on the science of the lightning rod. In this paper, the term "lightning rod or rod" will include all versions of the lightning rod, such as air terminals, dissipation arrays, charge transfer systems, and early streamer emissions, as the theory of each device is to deflect (from the protected asset) the lightning charge into the ground.

The current gold standard for lightning protection is the lightning rod. Building codes specify lightning rod protection. It has been the "go to" protection device since Ben Franklin's days. Today's version is more sophisticated, with more shape variations containing many more components and requiring maintenance to ensure the system will function as designed when struck by lightning. Most people are familiar with the installed rods on facilities, with the cable running to ground, as shown in **Figure 1**.

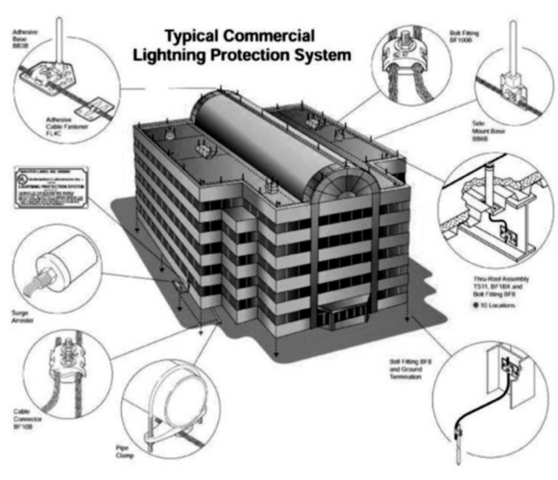

Figure 1. Typical Commercial Lightning Protection System

The installed rod is not designed to be an *attractor* of lightning. Rather the intent is for lightning that may develop in the immediate vicinity to hit the rod and not the facility. If properly installed, the electrical charge will go to ground and not affect the facility and equipment and people contained therein. In practicality, the EFI (electric field intensity) and EMP (electromagnetic pulse) of the lightning can affect equipment and people in the immediate area despite being properly installed. Current safety procedures require outside operations to be suspended when a lightning storm approaches. As detailed below, Brightex has the solution that allows operations to safely continue by *preventing* a conductive pathway for the lightning to travel from cloud to ground in the protected area.

Perfect lightning protection does not exist in our world at this time.

To again quote Dr. Uman: "Essentially perfect protection from both the direct currents and the electric and magnetic fields of lightning can be found inside a closed metal structure with an appropriate wall thickness and with no holes or openings (apertures) in the walls, including openings associated with wall penetrations by metallic conductors such as those carrying power and communication signals. Such a closed conducting structure is called an electrodynamic Faraday cage or simply a Faraday cage or Faraday shield." … "The concept of perfect lightning protection afforded by a Faraday cage is, unfortunately, of limited practical value." [2]

Can lightning be eliminated? To date the consensus is lightning cannot be eliminated; however, lightning can be "thwarted" by using a rejection or neutralization technique incorporating high-density plasma, which does not deflect the energy charge but blocks the path on which the lightning leader (from the cloud) and the streamer (from the ground) need to connect for the lightning energy to discharge. The charge emanating from ground objects is often referred to as corona.

III. FIRST AND ONLY ACTIVE LIGHTNING PROTECTION SYSTEM

III.a Technical Approach

The physics of lightning and lightning protection are not included in this paper. The calculations can be contained in a book by itself and can be discussed outside this presentation. The prevalent calculations pertain to lightning rod protection and *not* to the technology applied in the Brightex solution. The Brightex Compound Plasma Lightning Rejection (CPLR) solution as shown in **Figure 2** is unique and patented.

Figure 2. Compound Plasma Lightning (CPLR) Rejection System

The CPLR solution does not offer elimination of lightning nor does it try to redirect the energy of lightning to the ground. By utilizing high-density plasma, the CPLR solution provides the only ACTIVE lightning protection system that does not allow a conductive pathway to be developed between two points, which is required for the lightning energy to travel from cloud to ground in the protected area. This means that in the protected zone no property, equipment, or personnel are in danger of being struck by lightning. People are able to work in an open area while a storm passes over.

As stated above, the current standard for lightning protection is the lightning rod (no preventive action to keep lightning from striking). Protection is provided *after* a lightning event has occurred by providing the capability to ground the lightning event *after* it strikes the rod. In a practical sense, it is an attractor of lightning (intent of a rod is for lightning to be attracted to the rod and not the protected asset). The grounding system must be intact or the protected asset is damaged. Normally the rod is struck and the energy flows through the grounding system; however, there have been occasions where the lightning hit the protected asset rather than the installed rod. Furthermore, in many instances the EMP (electromagnetic pulse) of the lightning is able to escape from the grounding system and damages equipment and personnel within the facility or a neighboring facility. The complete protective system is rather intricate and not 100 percent failsafe.

When compared to the passive lightning rod with grounding cable and various components, the CPLR is simple in structure and uncomplicated in providing protection for your assets—property, equipment, and people, as well as profits. The CPLR provides area coverage (approximately 50 acres at maximum) which protects everything–buildings, stationary equipment, moving equipment, people, animals, trees, etc.—without each individual asset having its own *lightning rod*, as required using present-day technology.

The CPLR is patented in the USA, Canada and European Union. It is IEC approved and Underwriters Laboratories (UL) listed. The major components of the CPLR system, as shown in ***Figure 3*** and ***Figure 4***, are:

- Fore Alarm (a field mill device for EFI detection).
- Control Panel (control and monitor the plasma generator).
- Plasma chamber and dispersion rods (ion generator and ion flow).
- Fan and heater.
- Blower (for propelling the plasma ion field to atmosphere through dispersion rods).
- Frequency changer.
- High-frequency and high-voltage transformer.
- All components have been IEC approved and UL listed.

The CPLR technology actively shields assets from lightning damage in four integrated steps.

1. Detection is the first step. In his book, Dr. Uman emphasized the importance of tracking lightning. Brightex incorporates a Fore Alarm, as shown in **Figure 4**, into the system design. The Fore Alarm is the first step in providing active protection and measures the EFI of the storm clouds. The Fore Alarm is positioned with the CPLR in the area to be protected and operates continuously. As the storm clouds approach, the Fore Alarm measures the EFI between +/- 100

Figure 3. CPLR Components

kV/m. When the EFI is high, static electricity in the area is high, and the potential for lightning exists. Monitoring an approaching storm begins at a distance of 24 miles. When the EFI of the cloud reaches 20,000 V/m (EFI must be at least 20,000 V/m for lightning to develop), the plasma generator (CPLR) is activated.

Figure 4. Fore Alarm

2. Activate Generator: When the data sent by the Fore Alarm reaches a predetermined set point, the system control panel automatically activates the CPLR plasma generator. This set point is determined by the eminent EFI in the storm clouds approaching the protected area. Typically, this value is set to 20,000 V/m. When the EFI drops below the set point, the system control panel will shut down the plasma generator, and the Fore Alarm continues to operate.

Storms are unpredictable. As a precaution, if the storm cloud reverses its path, the generator runs for an additional 15 minutes after the EFI drops below the set point. When another lightning cloud is detected, the process repeats itself.

3. Generate Field: The generated high-density continuous plasma ion field consists of positive and negative ions in equal amounts over the protected area. The plasma ions are generated using a dielectric barrier discharge (DBD) system operating in a high-voltage and high-frequency electrical environment—positive and negative at the same time. The plasma is blown out through the dissipation rods.

4. Neutralize Pathway: The electric charge density of plasma ions generated by the plasma generator is higher than the surrounding static electric charge and electrically neutralizes the space between the storm cloud (both positive clouds and negative clouds) and the protected area. By weakening the electric field of the storm clouds, the CPLR system removes the potential for lightning to occur in the protected area. The ions density count (C/m^3) can be acquired using an instrument specific to such measures. This instrument is not part of the CPLR design.

III.b Neutralization and Rejection

The CPLR employs a proprietary and patented advanced process using high-frequency, high-voltage, high-density and low-temperature air plasma generator for lightning rejection and electrical storm cloud neutralization. For lightning rejection, it is not necessary to eliminate the total electric charge in the lightning cloud. What is required is to eliminate sufficient charge in the bottom of the cloud, where the lightning leader is developed. The total electric charge in a cell lightning cloud is usually 200 – 1000 Coulombs (abbreviated "C") with the typical charge being 300 C. The electric charge in the lightning leader path is 3 – 20 C and the typical value is 5 C. The electric charge transferred through lightning to the ground is usually 3 – 330 C, with the typical value being 30 C. It is only necessary to eliminate or suppress formation and development of the lightning leader. When this is done the lightning cloud will typically move away after approximately 30 minutes.

When activated, the CPLR generates a large volume of high-density plasma that is discharged through the end of each dissipation rod. The CPLR effectively neutralizes the electrical charge of the storm cloud over the protected area so as to weaken the electric field of the storm cloud and avoid voltage breakdown discharge (does not allow a conductive pathway for cloud-to-ground energy discharge).

The electric charge density of the CPLR plasma field (C/m^3) is approximately 200,000 times higher than the electric charge density of the approaching lightning storm clouds. Approaching lightning clouds usually have an electric charge density of 1x10^9 C/m^3. This higher charge density prevents the lower charge density ions in the cloud from being able to travel downward to complete a path to the opposite lower density ions from the earth's corona (self-induced static electric charge found on all objects on earth). When there is no path for the ions to travel and connect, there can be no transfer of energy in a lightning bolt. In other words, the lightning cloud moves past the protected area without lightning incidence.

III.c Additional Data

The CPLR, or plasma generator, can be situated on top of a building or tower at a height of approximately 31 m for maximum coverage in a populated area. Coverage provided is approximately 50 acres with a 250m radius of protection. In an open area, this radius will be extended because of less cumulative corona from ground objects. Each protected area is evaluated on its own merit and the CPLR installed on a fit-for-purpose basis.

The unit is web interfaced for Supervisory Control and Data Acquisition (SCADA) capability. Whereas earlier units functioned by means of a programmable logic controller (PLC), the CPLR 1000WI (current third-generation model) is microprocessor driven, as shown in **Figure 5**, and continues to offer remote monitoring and control. This approach presents a higher level of operating efficiency. The dimensions and weight of the system control panel have been significantly reduced thereby offering a much smaller footprint for wall or foundation mounting.

Figure 5. Control Panel

The airport operations group at Charlotte Douglas International Airport asked if the frequency of the CPLR would interfere with the operating frequencies of the airport. The question was submitted to the oversight FAA office in Atlanta. Their response was that the CPLR frequency is in the very low spectrum (50 kHz) and the airport's operating frequencies (civilian and military) are in the high spectrum (>100 MHz). Hence, there is no concern regarding interference.

The CPLR is designed to be a stand-alone protective system; however, because building codes require lightning rods, the CPLR can be integrated with a passive lightning rod. It should be noted that the CPLR would be installed at a height that is higher than the lightning rod. Thus, the lightning rod would be protected from a strike as well. With the CPLR operating, no lightning can strike within the protected area; therefore, operations need not be interrupted. Savings in air traffic delays and ground-support labor delays can run in the millions of dollars at larger airports, such as O'Hare International.

Power usage for the CPLR is extremely low. For each hour running time for the plasma generator, the power usage is approximately 3 kWh. When the plasma generator is not operating, only 100 W of power are spent to maintain the Fore Alarm (24/7 coverage) and Control Panel.

Technology is available to monitor and plot lightning strikes. This is accomplished through Google Mapping and a Microsoft program. This equipment is not included in the CPLR package.

III.d Result: Improved Lightning Protection Saving Dollars, Assets, and Lives

The most recent Brightex installation is at the Bali Indonesia International Airport. Prior to this installation the airport was repeatedly shut down during the 6-month monsoon season due to severe lightning strikes, even with lightning rod protection in place. Since August 2012, the airport has *not experienced one strike* in the protected area. An independent third party has verified this record and the following substantiation can be provided:

- Testimonials have been provided by the Bali airport personnel as to the effectiveness of the CPLR and the fact no lightning strikes have hit the protected area.
- The local weather station has installed the technology to track lightning events that occur. Photographs are available.
- Brightex has access to the web-interfaced CPLR in Bali and monitors the activity on a real-time continuous basis. As of 1 May 2014 (almost 2 years of running) the plasma generator has been activated more than 400 times and has run for over 21,000 minutes (over 350 hours).

IV. HISTORY OF BRIGHTEX

The technology presented in this paper does not deflect lightning nor does it eliminate lightning. The basis of the Brightex technology is to inhibit the traditional path of cloud-to-ground lightning thereby not allowing the energy contained in the cloud to travel to the earth.

BRIGHTEX™ USA

This new ACTIVE lightning protection technology was invented in 2001 by Dr. K.S. Kunsheng Wang, President of Euro-Asia Hi-Tech Development Co. Ltd. Dr. Wang is an expert in the field of modern applied power electronics and renewable energy applications. He earned his Ph.D. in physics from University of Leicester in England.

In 1995, Mr. Tun Aye Sai, who trained as a mining engineer and has over 40 years of experience in the mining, oil, and gas industries, is principal and founder of Brightex. He was introduced to and worked with Dr. Wang on developing power systems technology and equipment for environmental industries in Southeast Asia. Mr. Sai was intrigued with the concept of active lightning protection and followed Dr. Wang's progress. From 2002 to present, over 400 systems have been installed in the Far East. All sites for the CPLR installation were chosen due to continuous lightning storms causing damage and/or operational disruption. None of the protected sites has experienced a lightning strike after installation of the CPLR.

In 2008, Mr. Sai acquired the rights to market, distribute, and install the CPLR system worldwide. He established Brightex Holdings in Vancouver, BC, Canada. Brightex has offices in the U.S. and Indonesia, as well as representatives in other countries. Mr. Sai acquired the prototype design and through aggressive research and development has improved upon the CPLR technology. The current web interface model is the third generation of the CPLR. The CPLR unit is manufactured in Vancouver. Canadian-made products satisfy the U.S. Government purchasing requirements.

In 2013, Brightex USA was established in Charlotte, NC to develop the U.S. market. The Charlotte office is managed by Barry Jenkins, General Manager, and supported by Lee Binns, Director International Business Development. Mr. Binns is located in the Vancouver, BC corporate office and manufacturing facility.

V. SUMMARY: WHY THE BRIGHTEX CPLR IS SUPERIOR

Because of Ben Franklin, the lightning rod has been in existence for more than two centuries to protect facilities and structures from lightning strikes. The rod invites lightning to strike it rather than the object it is protecting so that the energy is diverted through a copper cable to a grounding system buried in the ground. This system has not proven to be dependable. The strong lightning electromagnetic pulse (LEMP) caused by a strike has the potential to damage nearby electronic devices and information networks. A classic example is the control tower in Maryland [3] that had lightning rod technology in place, but when hit by lightning the equipment went down, a controller was hurt and airport operations were shut down for hours.

The Active Brightex CPLR solution is superior in numerous ways as shown below:

1. Installation does not require a discharge of lightning current to ground with the potential for causing further damage.
2. No EMP to damage electronics or harm people after a strike.
3. Web interfaced system with SCADA control.
4. One CPLR provides 50 acres of coverage.
5. Coverage for property, equipment, ungrounded assets and exposed people. Individual protection, as required by rod technology, is not required.
6. For identical area coverage the cost to purchase and install a CPLR is similar to providing lightning rod coverage because each target requires a rod and grounding.
7. Flexible and simple installation, such as on an existing building or a small tower.
8. High-density, low-temperature plasma that solved the problem of previous attempts with DAS systems to use plasma to block lightning.
9. Simple and reliable concept. It does not compete with the physics of lightning.
10. Relatively lightweight system that has a small footprint.

11. Generator that is activated only when a storm is near and functions as a small energy user, which prolongs the life of equipment.
12. Can be installed for any topography and positioned with no change in design.
13. Each application fit-for-purpose.
14. Mobile objects are fully protected.
15. Simplicity of design that reduces maintenance expenses.
16. Eliminates risk of lightning striking in the protected zone.
17. Uninterrupted operational activities in protected zone during a lightning event.
18. Potential for significantly reduced insurance premiums.

Without a doubt, the most credible fact is that the technology has been field tested for years and has proven 100% effective to date. The applications for this technology are many. **Figure 6** lists potential applications.

LIFE SAFETY	INFRASTRUCTURE	COMMERCIAL
Hospitals, Schools	Power Generating and Distribution Plants	Mining, Oil, Gas and Petrochemical Facilities
Sport Centers	Telecommunication Infrastructures	Manufacturing and Industrial Facilities
Public Recreational Facilities	Military and Defense Installations	Information Technology and Data Centers
Residential Areas and Commercial Centers	Airports, Harbours and Railway Stations	Tourism Industry
Retail Malls and Outlets	Meteorological Sites	Banking and Broadcasting Industries

Figure 6. Potential Applications of CPLR Technology

Risk management studies demonstrate that early action to minimize or eliminate risk is a good business practice. Lightning is a known risk, but many companies do not address any active measures and instead rely on insurance or repair and replacement after the passive lightning protection system allows lightning strikes. Brightex offers another solution to lightning protection that removes the risk and will not allow lightning to hit an airport. Operations can continue uninterrupted during a lightning event.

Our mission is to help manage risk that in turn helps minimize losses due to aircraft and labor delays.

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